INHERITANCE OF FERTILITY IN SOUTHDOWN SHEEP[1]

EDWARD N. WENTWORTH

Professor of Animal Breeding

AND

J. B. SWEET

Assistant in Experimental Breeding, University of Wisconsin

Introduction

Youatt (14)[2] says:

> The disposition to twinning is undoubtedly hereditary:
>
> "Ewes yearly by lambing rich masters do make:
> The lambs of such twinners for breeders go take."

Flockmasters of the last century have made selections on this assumption, while the increased number at a birth in the progeny of ewes born multiparously as compared to the progeny of those born singly has been demonstrated by several investigators. In general there has been shown to be an increase in number produced at a birth as the average birth values of the animals lambing increase. Thus, Rietz and Roberts (13) present the following in Shropshires, the number at a birth being represented by the figures 1, 2, or 3:

Sire	Dam	Offspring	No. Cases
1	1	1.3452 ± 0.0059	3,059
2	1	1.3946 ± 0.0073	2,088
1	2	1.4171 ± 0.0067	2,436
2	2	1.4548 ± 0.0088	1,550
One parent a triplet		1.6076 ± 0.030	158

Experimental investigations of the inheritance of twinning in sheep have been attempted in few cases. Ains-

[1] Paper No. 5 from the Laboratory of Animal Technology, Kansas Experiment Station.

[2] Reference is made by number to literature cited at close of paper.

worth-Davis and Turner (1) reported a preliminary investigation on this subject, but their numbers are too small and results too contradictory, as published, even to be indicative of the method of inheritance. Arkell and Jones (7) at the New Hampshire station also instituted investigations along this line, but have published no results.

Due to the environmental and physiological factors involved in multiple births, as well as to the economic impracticability of maintaining large flocks under rigid experimental conditions, there are at hand no considerable masses of experimental data which yield evidence on this point, nor are the probabilities great that such experiments will ever be conducted on an adequate scale; hence the bulk of evidence on the inheritance of fertility must come from breeders' flocks or from breed registry records.

The Fertility Problem

High fertility obviously depends on three factors—the number at a birth the frequency of reproduction, and the total number of successful gestations an animal may undergo. Unfortunately flock book records give available data on the first point only, although for specific cases some evidence on the second point (barring abortions and unregistered progeny) exists.

For breeding purposes the number of successful gestations is not a practical selective index, since the breeder can not afford to withhold progeny from breeding until their dams or sires shall have completed their breeding cycles. Frequency of reproduction or regularity of breeding as termed by the breeder is a more practicable trait for purposes of selection, but since barren reproductive periods are so much more frequently due to pathological or physiological causes than to genetic, most sheepmen lay principal emphasis on the number of offspring at the given birth.

There are two ways in which selection on this basis may be applied. The ewe may be selected on the basis of

a particular lambing, or the basis of the best lambing she shows. From a genetic standpoint the second criterion would seem the better, but practical breeders would be very likely to use the first. Unfortunately, records in Southdowns on which a comparison can be based are few, forty-three animals only being available. Table I presents the correlation of each individual record with the average lambing record for each ewe, while Table II presents the correlation of the best record for each ewe with her average. Nine of the ewes had four lambings to their credit, nine had three, while twenty-five had only two. The inadequacy of these data is recognized, since there is a false agreement between a single number and its average with another as compared to its agreement with its average with several numbers. Since, however, the material is suggestive from a comparative standpoint, it is presented, as the same actual error exists in each table:

TABLE I

CORRELATION OF INDIVIDUAL LAMBING WITH AVERAGE LAMBING PER EWE

Average Lambing per Ewe

Individual	1	1.5	1.67	1.75	2	2.5	F
1	38	6	4	4	1	0	53
2	0	6	8	12	31	1	58
3	0	0	0	0	1	1	2
Total	38	12	12	16	33	2	113

The coefficient of correlation for this table is 0.81806 ± 0.02099.

TABLE II

CORRELATION OF BEST LAMBING RECORD WITH AVERAGE OF EACH EWE

Average Lambing of Ewe

High Record	1.00	1.50	1.67	1.75	2.00	2.50	F
1	16	0	0	0	0	0	16
2	0	4	4	4	13	0	25
3	0	0	0	0	1	1	2
Total	16	4	4	4	14	1	43

The coefficient of correlation for Table II was found to be 0.92354 ± 0.01513.

While both records show a higher agreement with the average than probably exists in actual selections, the fact that the best record is more closely in agreement with the average than a random record makes high production a significant selection standard. The correlation between random records and the best records is presented in Table III.

TABLE III

BEST RECORD OF EWE

Individual Record	1	2	3	F
1	38	14	1	53
2	0	55	3	58
3	0	0	2	2
Total	38	69	6	113

The coefficient of correlation here is 0.6518 ± 0.03665. The relationship is not as great as between either of the records and the average record, as shown in Tables I and II. Since the correlation is not as high, and since an error (false agreement with the average) is introduced into each of the first two tables, it is well to determine whether the difference between the first two correlation coefficients is significant. Using the formula for the standard deviation of the difference between the first two constants presented by Pearl (10): Error of $(x-y) = \sqrt{E_x^2 + E_y^2 - 2\, r_{xy}\, \sigma_x\, \sigma_y}$, where E refers to the error, x to the larger constant, y to the smaller, and r_{xy} to the correlation between x and y. The error of the difference between the correlation coefficients of Tables I and II is 0.01598. Since the difference is .10548, it is greater than three times the probable error, hence it is justifiable to conclude that the highest number at a birth is a better indication of the average fertility of an animal than a random birth, although on the basis of the figures presented the latter relationship is high.

Youatt (14) reports in 1837 that one ewe out of five in the average English flock produced twins, which would give 120 per cent. of lambs as the proportion of English flocks at that time.

Mansell (12) reports 168 per cent. of lambs in 11,668 English Shropshires in 1896, while Humphrey and Kleinheinz (6) from figures on the University of Wisconsin flock made the following breed comparisons:

TABLE IV

Breed	Singles		Twins		Triplets	
	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
Shropshire	42	23.7	120	67.8	15	9.5
Dorset	10	33.3	20	66.7	0	0.0
Southdown	27	38.0	44	62.0	0	0.0
Oxford	3	13.6	16	72.8	3	13.6
Hampshire	9	31.0	20	69.0	0	0.0
Cheviot	9	31.0	20	69.0	0	0.0

Percentage of lambs as given by Mansell is, of course, only a rough indication of twin-bearers, since ewes having triplet and quadruplet births may be included.

Rietz and Roberts (13) show that 43 out of every 100 births in American Shropshires are multiple births, while they have determined from Heape's (5) statistics of 1895–96 that 64 out of every 100 births in English Shropshires are multiple.

Plumb (12) found in 20,037 Shropshire births 59.2 per cent. were singles, 39.2 per cent. twins, and 1.3 per cent. triplets, all recorded in the American Shropshire Flock Book, 1890 to 1899.

Heape (5), from a study of the birth records of 89,000 ewes in English flocks, presents the following data to show the relative fertility of different breeds of sheep:

TABLE V

Breed	Per Cent. Lambs per Ewe	Per Cent. Twin Bearing Ewes
Suffolk	141.77	52.22
Kent	124.05	31.38
Southdown	109.89	18.67
Hampshire	114.69	24.09
Oxford Down	119.16	35.02
Dorset Horn	123.63	37.55
Shropshire	136.79	46.84
Lincoln	111.10	29.09

The figures for the per cent. of lambs per ewe and the per cent. of twin-bearing ewes do not in all cases check each other, as records of certain ewes were available for the one column but not for the other.

The writers tabulated birth frequencies in Shropshires, Cotswolds and Dorsets with the following results:

TABLE VI

Breed	Singles		Twins		Triplets		Quadruplets	
	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
Shropshire	10,585	69.41	4,561	29.91	102	.67	2	.01
Dorset	2,143	67.75	956	30.22	57	1.88	7	.22
Cotswold	5,523	79.24	1,431	20.53	16	.23		

Dorsets seem to have an exceptionally high percentage of triplets and quadruplets.

Factors Affecting Fertility

Heape (5) in a study of 122,673 breeding ewes, 413 English flocks, suggests five physiological factors that may affect the hereditary expression of fertility. The most important factor according to him is the physical condition of the ewe, which must be vigorous and healthy, especially at tupping (mating) time. The second most important factor is the feeding of the ewe, especially flushing previous to breeding, and careful diet during gestation. The third factor in importance is the district; he cited the fact that the Suffolk in its native country produced 60.46 per cent. of twins, while in Essex it produced only 42.87 per cent. The fourth factor in importance he found to be the age of the ewe; and the fifth, the season of year at which mating occurred.

Carlyle and McConnel (3) at Wisconsin discuss time of mating and age of ewe, factors similar to those mentioned by Heape. In a study of twelve years of records of the station flock at the University of Wisconsin they found that ewes bred early in the season dropped a higher percentage of lambs than those dropped late in the season,

while ewes from three to six years of age seemed to be at the optimum breeding period of their life. Humphrey and Kleinheinz (6) found that two-year-old ewes produced 141 per cent. of lambs and six-year-olds, 191 per cent. Possibly the writers do not understand the tables presented by them, but their calculations on the basis of the data there given would show the following averages at each age:

TABLE VII

Age	Average No. per Birth	No. Cases
2	1.54	53
3	1.56	52
4	1.71	52
5	1.73	57
6	1.92	24
7	1.45	11
8	1.00	2
9	2.00	2

Pearl (9) made a biometric study of the fertility of a long-lived ewe whose breeding record was as follows:

TABLE VIII

		Lambs		Lambs
April,	1806	1	1816	2
	1807	1	1817	2
	1808	2	1818	2
April 3,	1809	3	1819	2
Mar. 29,	1810	3	1820	2
	1811	3	1821	1
	1812	3	1822	1
	1813	3	1823	0
	1814	3	1824	0
	1815	2	Total	36

Assuming that the ewe was about one year old when the first lamb recorded was born, Pearl found that the mean point of the ewe's effective breeding life was 8.57 years, that the median point was 8.17 years and that the modal breeding point, or the point of maximum fertility per unit of time, was at 7.34 years.

Taking into account the seventeen years in which some young were born, the following constants regarding the number of lambs per birth were found:

Mean number of lambs per birth, 2.12 lambs.

Standard deviation in number of lambs per birth, 0.76.

Coefficient of variability in number of lambs per birth, 35.78 per cent.

Marshall (8) found after a study of the lambing statistics for various flocks of Scottish sheep for the years 1905, 1906, and 1907, that the percentage of lambs born was, as a general rule, highest among sheep which had been subjected to a process of artificial stimulation by means of special diet at the approach of the breeding season. In some cases the number of lambs per ewes in the "flushed" flocks was nearly 200 per cent. Flocks which were run upon special pasture upon the approach of the tupping season generally produced a slightly larger percentage of lambs than those receiving no sort of special feeding. Evvard (4) found among range ewes fed the same ration that the fourteen heaviest gaining ewes at time of breeding in his flock averaged 1.8 lambs; the fourteen medium gainers, 1.59; and the fourteen lightest gainers, 1.44.

Relation of Mammæ to Fertility

Alexander Graham Bell (2) conducted an experimental investigation on the relation of the number of mammæ to fertility. An unusually high fertility among a flock of native sheep in Beinn Breagh, Nova Scotia, led Bell to examine the ewes in order to discover some distinguishing mark of the twin-bearing ewe. He found a certain number of ewes with one to two supernumerary nipples in an embryonic, functionless condition. Of these abnormally nippled ewes, 43 per cent. had twin lambs, while of the normally nippled ewes but 24 per cent. produced twins. This apparent correlation between multinipples and increased fertility led to an extended series of experiments to ascertain whether by selective breeding, the supernumerary nipples could be made functional, and whether ewes with additional mammæ in a functional condition were more fertile than ewes with the normal number of nipples.

No difficulty was experienced in obtaining ewes that produced milk from six nipples. These multi-nippled sheep, however, did not prove to be more fertile than normally nippled sheep. In his 1912 paper (2) he states that the indications are that the six-nippled stock will ultimately prove to be twin bearers, as a rule, at maturity.

METHOD OF OBTAINING DATA

The source of the data in the present study was the American Southdown Record, the first twelve volumes being used to obtain cases of triplets, and volumes nine to twelve for twins and singles. The pedigree of each animal was reported into the third generation, recording the numbers of offspring at the birth of each animal. Some records on triplets were also taken from the American Shropshire Record, while Volume 25 was used to determine the ratio of singles, twins and triplets, Volumes 9–12 of the Southdown Flock Book for the same purpose, Volumes 12, 13, and 14 of the Continental Dorset Club Record, and Volumes 11 and 12 of the American Cotswold Record.

RELIABILITY OF FLOCK BOOK DATA

Records of the number at a birth in sheep are probably highly accurate for such material, since there is no observable tendency to discriminate in favor of, or against, recording offspring of multiple births, except the indirect one of lesser development in offspring from multiple births. This would not affect the reliability of the figures presented by the flockmaster, except perhaps to reduce slightly the proportion of multiple births registered. It may be safely assumed that the bulk of the records are accurate, barring clerical error.

THE NUMBER AT A BIRTH AS A GENETIC INDEX

Due to the physiological causes limiting the full expression of the genetic fertility of an animal it is obvious that animals recorded as singles may be potentially twin or

triplet bearers, or that ewes recorded as bearing twins may be genetically triplet producers or better. Hence it may be expected that not all single or twin bearers are alike in zygotic make-up with reference to fertility or that their breeding performance will fall into sufficiently well-defined categories to permit a rigorous Mendelian grouping. The relation between a random lambing record and the average record of ewes was shown earlier in this paper to be high, hence a similar relation might be expected to hold for true genetic fertility, were it measurable, and a random record.

The Data Involved

The Relative Influence of Sire and Dam.—Rietz and Roberts (12) found a mathematically significant effect of the sire on the number at birth as adjudged by the correlation between offspring and sires, although they do not find a similar relation between dams and maternal grandsires. While the authors have not secured correlation coefficients on this point, their averages may be so arranged as to throw some light on the same point. Using pedigrees which were started from animals of single birth, the following comparison between sires and dams is possible.

TABLE IX

Relative Influence of Sire and Dam on Birth Number, from Pedigrees of Animals of Single Birth

No. Cases	Sire	Dam	Ave. No. Progeny	No. Cases	Sire	Dam	Ave. No. Progeny
1,872	1	1	1.29	1,872	1	1	1.29
925	1	2	1.28	570	2	1	1.25
14	1	3	1.43	12	3	1	1.50
5,570	2	1	1.25	925	1	2	1.28
306	2	2	1.34	306	2	2	1.34
10	2	3	1.20	6	3	2	1.17
12	3	1	1.15	14	1	3	1.43
6	3	2	1.17	10	2	3	1.20

Comparison of the records of single, twin and triplet sires mated to single, twin and triplet ewes in the preceding table shows no particular influence of the birth rank of the sire, a fact which is confirmed in Table X, where the average performance of each is given.

TABLE X

BREEDING PERFORMANCE OF THE MALES FROM PEDIGREES STARTED WITH SINGLE BIRTHS

Sires	Mean	Standard Deviation	No. Cases
1................	1.2864±.00593	.4668	2,811
2................	1.2776±.01031	.4553	886
3................	1.3888±.07750	.4875	18

The difference between the breeding performance of the singles and twins is 0.0088 ± 0.0119, which is, of course, not sufficient to be significant. It indicates either that the male has no influence on the number at a birth (the most probable supposition) or that singles and twins in the males are genetically similar. The difference between the breeding performance of the triplets and singles is 0.1024 ± .0777 and between the triplets and twins is 0.1112 ± .07818, neither of which is significant.

For the ewes the result is not particularly different. Table XI presents the result of this comparison.

TABLE XI

BREEDING PERFORMANCE OF THE FEMALES FROM PEDIGREES STARTED WITH SINGLE BIRTHS

Dams	Mean	Standard Deviation	No. Cases
1................	1.26365±0.00631	.4635	2,454
2................	1.29345±0.00893	.4658	1,237
3................	1.33333±0.06490	.4714	24

The difference between the progeny of ewes born singly and those born twins is .01349 ± 0.1093; between singles and triplets is .05338 ± 0.06252; and between twins and triplets is .03989 ± 0.0655.

TABLE XII

RELATIVE INFLUENCE OF SIRE AND DAM ON BIRTH NUMBER, FROM PEDIGREES OF ANIMALS OF TWIN BIRTH

No. Cases	Sire	Dam	Ave. No. Progeny	No. Cases	Sire	Dam	Ave. No. Progeny
2,805	1	1	1.51	2,805	1	1	1.51
1,294	1	2	1.55	687	2	1	1.57
21	1	3	1.86	19	3	1	1.68
687	2	1	1.57	1,294	1	2	1.55
468	2	2	1.56	468	2	2	1.56
10	2	3	1.60	7	3	2	1.43
19	3	1	1.68	21	1	3	1.86
7	3	2	1.43	10	2	3	1.60

Table XII shows the relative breeding performance of the sires and dams in pedigrees started from twin births.

Treating the sires in pedigrees from twin births as in Table X, Table XIII is produced.

TABLE XIII

BREEDING PERFORMANCE OF THE MALES FROM PEDIGREES STARTED WITH TWIN BIRTHS

Sires	Mean	Standard Deviation	No. Cases
1................	1.5296 ± .00543	.51659	4,120
2................	1.5682 ± .00724	.49704	1,165
3................	1.6154 ± .06435	.48650	26

The difference between singles and twins as sires is .0386 ± .0091; between singles and triplets is .0858 ± .0645; and between twins and triplets is .0472 ± .0647. The difference between singles and twins is in this case significant, being about 4.2 times the probable error. Further consideration will be given this difference when the ewes are discussed.

Treating the ewes in pedigrees from twin births as in Table XI, Table XIV is produced.

TABLE XIV

BREEDING PERFORMANCE OF FEMALES FROM PEDIGREES STARTED WITH TWIN BIRTHS

Dams	Mean	Standard Deviation	No. Cases
1................	1.2529±.00581	0.51075	3,511
2................	1.5551±.00827	0.51583	1,769
3................	1.7742±.05065	0.41811	31

The difference between singles and triplets is 0.2513 ± .05098; between twins and triplets, 0.2191 ± .05132; and between singles and twins is 0.0322 ± .01011. Ewes from triplet births give significantly larger progenies than ewes from single or twin births, while ewes from twin births give significantly larger progenies than ewes from single births, the last difference being 3.323 times the probable error. It is interesting to observe that both

twin rams and twin ewes are significantly better breeders than singles. Just why this result is obtained here in the face of other contradictory data is difficult to understand.

In order to combine the results of the two types of pedigrees it was deemed advisable to utilize the ratio of 1:4.118 twins to singles discovered by examination of volumes 9 to 12, respectively, in order to have the normal relationship between twins and singles. This involved dividing the numbers of individuals in the twin group or multiplying those in the single group. In the first case errors would be increased, due to the elimination of certain groups, while in the second case errors would be increased due to the exaggeration of differences between the random sample in the pedigrees begun from single births and the normal distribution of such a population. It was deemed best to use the second method, since it permitted the retention of the small groups, hence the ratio 1:4.118 was multiplied by the ratio 3,715:5,311, the numbers of individuals in the pedigrees from twin and single births, respectively, which gave the multiplying factor 5.887 for the pedigrees started from single births. Of course, this result is only suggestive; but it was impractical to record the additional 4,300 odd pedigrees necessary to get a true random distribution. Treated this way, multiplying Table V by 5.887 and adding to Table IX, Table XV is produced.

TABLE XV

No. Cases	Sire	Dam	Ave. No. Progeny	No. Cases	Sire	Dam	Ave. No. Progeny
13,826	1	1	1.33	13,826	1	1	1.33
6,739	1	2	1.33	4,043	2	1	1.33
1,103	1	3	1.51	89	3	1	1.54
4,043	2	1	1.30	6,739	1	2	1.33
2,270	2	2	1.38	2,270	2	2	1.38
69	2	3	1.26	42	3	2	1.21
89	3	1	1.54	1,103	1	3	1.51
43	3	2	1.21	69	2	3	1.26

Treating the sires as in Tables VI and X, Table XVI is produced.

TABLE XVI

BREEDING PERFORMANCE OF THE MALES GIVEN IN TABLE XI

Sires	Mean	Standard Deviation	No. Cases
1................	1.3340 ± .00229	.48658	20,668
2................	1.3308 ± .00403	.47677	6,382
3................	1.3318 ± .2908	.49533	132

The difference between singles and twins is .0032 ± .0463; between singles and triplets, .0978 ± .02916; and between twins and triplets, .1010 ± .02936.

TABLE XVII

BREEDING PERFORMANCE OF FEMALES FROM TABLE XV

Dams	Mean	Standard Deviation	No. Cases
1................	1.3274 ± 0.00243	0.48261	17,958
2................	1.3444 ± 0.00345	0.48713	9,052
3................	1.4128 ± 0.02533	0.49234	172

The difference between singles and twins is found to be 0.0170 ± 0.00422; between singles and triplets, 0.0854 ± 0.02545; and between twins and triplets, 0.0684 ± 0.02556. Several of the differences in Tables XV and XVI verge on significance, being at least three times the probable error.

RELATIVE INFLUENCE OF MALE AND FEMALE IN GRANDPARENTS

From the study of the relative influence of the sires and dams on the progeny it would seem fruitless from biometric grounds to look for transmission through one sex more than the other. Yet logically it would seem that the grandsire and grandam on the dam's side would have a more potent effect on the birth number from the dam than would the paternal grandparents. Studies of this sort are available from the pedigrees. Perhaps the first concern is to determine the relation of the birth rank of the grandparents to that of the progeny. Table XVIII presents this information.

TABLE XVIII

RELATION OF BIRTH FREQUENCIES IN GRANDPARENTS TO BIRTH FREQUENCIES OF PROGENY

Grandsire	Grandam	Ave. Birth Ranks	Ave. Progeny	Standard Deviation	No. Cases
1	1	1	1.6500±.00881	.5451	1740
1	2	1.5	1.7041±.01488	.6030	747
2	1	1.5	1.7065±.01923	.5717	402
2	2	2	1.7500±.03328	.5517	308
1	3	2	1.8095±.08642	.5871	21
3	1	2	2.0000±.07855	.0000	6
2	3	2.5	1.6667±.08297	.5634	21
3	2	2.5	1.7500±.14606	.4331	4

The difference between the average progeny from grandparents 1♂ × 1♀ and grandparents 2♂ × 1♀ is .0579 ± .02114. This is not three times the probable error, therefore the difference is not significant. The difference between grandparents 1♂ × 1♀ and grandparents 1♂ × 3♀ is .1609 ± .08687. This also is less than three times the probable error, hence is insignificant. In fact none of the differences are significant.

To determine whether birth rank in males or females among the maternal grandparents has effect on transmission, they were compared in the same manner as the sires and dams were. The results for grandsires are:

TABLE XIX

RELATION OF BIRTH RANK OF GRANDSIRE TO BIRTH RANK OF PROGENY

Birth Rank of Grandsire	Ave. Progeny	Standard Deviation	No. Cases
1	1.6675±.00760	.5643	2,508
2	1.7209±.01442	.5779	731
3	1.9000±.06399	.3000	10

The difference between singles and twins is .0534 ± .0163; between twins and triplets is .1791 ± .06559; and between singles and triplets is .2125 ± .06444. The difference between singles and triplets is 3.62 times the probable error, while the difference between singles and twins is 3.34 times its probable error.

Treating the dams in the same manner as the sires Table XX is produced:

TABLE XX

RELATION OF BIRTH RANK OF GRANDAM TO BIRTH RANK OF PROGENY

Birth Rank of Grandam	Average Progeny	Standard Deviation	No. Cases
1	1.6615 ± .00737	.5064	2,148
2	1.7177 ± .01239	.5979	1,059
3	1.7381 ± .06034	.5798	42

The difference between singles and twins is .0562 ± .01435; between singles and triplets is .0766 ± .06079; and between twins and triplets is .0204 ± .06159. The only significant difference is between singles and twins, which is 3.88 times the probable error.

The probable errors involved seem to indicate little, hence a comparison by correlation of the maternal grandsire and progeny, and maternal grandam and progeny was instituted. Table XXI presents the correlation for the maternal grandsire, Table XXII for the maternal grandam.

TABLE XXI

CORRELATION OF MATERNAL GRANDSIRE AND PROGENY

Birth Rank Grandsire	Birth Rank Progeny				f
	1	2	3	4	
1	954	1,435	118	1	2,508
2	251	431	49		731
3		9	1		10
f	1,205	1,875	168	1	3,249

TABLE XXII

CORRELATION OF MATERNAL GRANDAM AND PROGENY

Birth Rank Grandsire	Birth Rank Progeny				f
	1	2	3	4	
1	811	1,254	82	1	2,148
2	381	596	82		1,059
3	3	25	14		42
f	1,195	1,875	178	1	3,249

The coefficient of correlation for Table XXI is .0496 ± .0118, while for Table XXII it is .0382 ± .0118. The difference between the correlations of maternal grandsire

and grandam is .0114 $\pm$ .0167, a difference insignificant, hence one can not assume sex linkage.

Examination of Shropshire Data from the Mendelian Standpoint

A number of Shropshire pedigrees were tabulated which were all started from triplet births. It had seemed from inspection that triplets might be genetically different from twins and singles, hence the pedigrees were tabulated to discover such a difference if possible. If the maternal grandparents affected the number at a birth from their daughter, then it was possible that certain differences might appear in the pedigrees indicating the genetic effects. The results follow.

TABLE XXIII

Relation of Birth Rank in Offspring to Birth Rank in Dam when the Maternal Grandparents are Singles

Offspring

Dam	1	2	3	4	Mean	Standard Deviation
1...........	17	16	17	0	2.00	0.824
2...........	12	10	15	1	2.13	0.894
3...........	0	0	1	0	3.00	0.000

TABLE XXIV

When Maternal Grandsire is a Single and Maternal Grandam is a Twin

Offspring

Dam	1	2	3	Mean	Standard Deviation
1...........	15	9	15	2.00	0.873
2...........	10	9	25	2.34	0.825
3...........	5	0	0	1.00	0.000

TABLE XXV

Maternal Grandsire a Twin, Maternal Grandam a Single

Dam	1	2	3	Mean	Standard Deviation
1...........	8	3	13	2.21	0.912
2...........	7	5	7	2.00	0.858
3..........	1	0	0	1.00	0.000

TABLE XXVI

MATERNAL GRANDPARENTS TWINS

Dam	1	2	3	Mean	Standard Deviation
1...........	4	2	4	2.00	0.895
2...........	9	9	9	2.00	0.817
3...........	0	1	2	2.67	0.417

TABLE XXVII

MATERNAL GRANDSIRE A TRIPLET, MATERNAL GRANDAM A SINGLE

Offspring

Dam	1	2	3	Mean	Standard Deviation
1...........	0	0	0	0.00	0.000
2...........	0	1	0	2.00	0.000
3...........	0	0	0	0.00	0.000

TABLE XXVIII

MATERNAL GRANDSIRE A SINGLE, MATERNAL GRANDAM A TRIPLET

Offspring

Dam	1	2	3	Mean	Standard Deviation
1...........	0	0	0	0.00	0.000
2...........	0	0	1	3.00	0.000
3...........	0	0	1	3.00	0.000

TABLE XXIX

MATERNAL GRANDSIRE A TRIPLET, MATERNAL GRANDAM A TWIN

Offspring

Dam	1	2	3	Mean	Standard Deviation
1...........	0	0	0	0.00	0.000
2...........	1	0	0	1.00	0.000
3...........	0	0	0	0.00	0.000

TABLE XXX

MATERNAL GRANDSIRE A TWIN, MATERNAL GRANDAM A TRIPLET

Offspring

Dam	1	2	3	Mean	Standard Deviation
1...........	0	0	1	3.00	0.000
2...........	0	1	1	2.50	0.500
3...........	0	0	0	0.00	0.000

Since all the pedigrees were started from triplets the excess of triplets is so great as unduly to weight the ratios. Inspection of the ratios does not reveal any particular difference in the progeny descended from a particular pair of grandparents, whether the dam is a single, twin or triplet. Since also there seems to be no sex linkage involved it seemed desirable to combine similar matings from the standpoint of birth rank. The totals produced are presented in Table XXXI.

TABLE XXXI

SUMMARY OF TABLES XXIII TO XXX WITH RESPECT TO BIRTH RANK OF MATERNAL GRANDPARENTS

No. Offspring

Birth Rank Maternal Grandparents	1	2	3	4	Mean	Standard Deviation
Both grandparents single...	29	26	33	1	2.07	0.85851
One grandparent a twin....	46	26	60	0	2.11	0.88983
Both grandparents twins...	13	12	15	0	2.05	0.83516
One grandparent a triplet..	1	2	4	0	2.43	0.70855

Confirmation of the previous view that twins and singles are genetically alike, while triplets differ from either, seems to be found in Table XXXI. However, the difference between triplets and the mating where one grandparent is a twin is only 0.32 ± 0.20. This is not three times the probable error, but by consulting Pearl and Miner's (11) table it is found that the chances that the difference is significant are about two and a half to one.

CONCLUSIONS

1. In general sheep of a high birth rank tend to produce offspring of a high birth rank.
2. On the basis of the few data presented, the highest record of a ewe appears to be a better selection standard for high fertility than a random record.
3. The frequency of multiple births in sheep varies with the breed.
4. Physiological factors may exert a marked influence

on heredity, the most important factors being the vigor of ewe, the feeding of ewe, the age of ewe, the season and the region.

5. Apparently no relation exists between high fertility and additional mammæ.

6. In pedigrees started from single births, the birth rank of the sire does not affect the birth rank of the progeny; in pedigrees started from twin births, the effect of high birth rank of the sire is only slightly significant (more than three times the probable error).

7. The effect of birth rank of ewe on the birth rank of progeny is the same as that of the sire except in the case of pedigrees started from twin births when it is slightly greater.

8. No evidence for a sex linkage of fecundity factors occurs in the pedigrees tabulated, as shown by a comparison of the relative influence of progeny of the maternal grandam and the maternal grandsire.

9. Evidence from Shropshire triplet pedigrees suggests that triplets are genetically different from twins and singles, which two are probably genetically alike.

LITERATURE CITED

Ainsworth-Davis, J. R., and Turner, D.
1913. Fecundity of Sheep. In V Cong. Internat. Agr. Gand., Sec. 3, question 4, p. 5.

Bell, Alexander Graham.
1904. The Multinippled Sheep of Beinn Breagh. In *Science,* N. S., Vol. 19, p. 767.
1912. Sheep Breeding Experiments. In *Science,* N. S., Vol. 36, pp. 378–84.

Carlyle, W. L., and McConnell, T. F.
1912. Some Observations on Sheep Breeding from the Experimentation Flock Records. In Wisconsin Sta. Bul., 95, p. 19.

Evvard, J. M.
1913. Unpublished Data.

Heape, Walter.
1899. Abortion, Barrenness and Fertility in Sheep. In *Journal of Royal Agr. Soc. England,* 3d series, Vol. 10, pp. 234–248.

Humphrey, Geo. C., and Kleinheinz, Frank.
1907. Observations on Sheep Breeding from Records of the University Flock. In 24th Annual Report, Agr. Exp. Sta., University of Wisconsin, pp. 25–41.

Jones, J. M.
1912. Sheep Breeding and Feeding Experiments. In New Hampshire Sta. Bul., 163, pp. 24–28.
Marshall, F. H. A.
1910. Physiology of Reproduction. London, p. 598.
Pearl, Raymond.
1913. Note Regarding the Relation of Age to Fecundity. In *Science*, N. S., Vol. 37, pp. 226–228.
1917. The Probable Error of a Difference and the Selection Problem. In *Genetics*, Vol. 2, No. 1, p. 78.
Pearl, Raymond, and Miner, John Rice.
1914. A Table for Estimating the Probable Significance of Statistical Constants. In Papers from the Biological Lab. No. 63, Bul. 226. Maine Agr. Exp. Sta., p. 88.
Plumb, Charles S.
1906. Types and Breeds of Farm Animals. Boston, p. 391 (cites data of Mansell's).
Rietz, H. L., and Roberts, E.
1915. Degree of Resemblance of Parents and Offspring with Respect to Birth as Twins for Registered Shropshire Sheep. In U. S. Dept. Agr., *Jour. Agr. Research*, Vol. 4, No. 6, pp. 479–510.
Youatt, Wm.
1837. Sheep, Their Breeds, Management and Diseases. London, p. 508.